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Phylogenetic Analysis of the Cetonini of the New World (Coleoptera: Scarabaeidae: Cetoninae)

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PHYLOGENETIC ANALYSIS OF THE CETONIINI OF THE NEW WORLD (COLEOPTERA: SCARABAEIDAE: CETONIINAE)

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ABSTRACT

The American genera of Cetoniini (Coleoptera: Cetoniinae) are analyzed. Fifty-eight morphological characters of seventy two taxa, including Cetoniini from the entire world and other representative tribes of Cetoniinae, were included in a phylogenetic analysis and studied under the parsimony criterion. The Cetoniini, a tribe including species from all continents, is monophyletic and appears supported by two homoplastic characters: the elytra-thorax articulation in a glove-like shape and the mesosternal process basally compressed and apically expanded in shape. No clade supporting a hypothesis of common ancestry for the American species was found. Of the traditionally defined genera in the American continents only *Chlorixanthe* was monophyletic and positioned basal to the Cetoniini clade. *Stephanucha* and *Euphoriopsis* are paraphyletic with respect to *Euphoria* and are transferred to this genus. *Euphoria holochrolis* is resurrected, considered a valid species and sister to the fulgida group. *Euphoria* represents a poorly defined polyphyletic genus with a great degree of variability, with some species closer to European and African lineages rather than those within *Euphoria*.

INTRODUCTION

The understanding we have about life on earth and its evolutionary history comes traditionally from a couple of sources. First we can study the organism, studying its parts and how these parts function and how they interact with each other. Second we can the study the organism as one that belongs to a lineage that varies through time by trying to frame it within an evolutionary scenario. These are not always straightforward processes and hence it can take numerous years and many biologists working in different fields to produce this kind of knowledge. Nevertheless this type of information is not predictive in a way it can be contrasted and in essence constitutes basically a description of a natural process whether known from molecules or morphology.

Another way we can understand life is via a historical method by looking at groups defined by common ancestry. Analysis of the traits of a chosen collection of organisms under study is used to infer the identity of a group that through time forms a unique lineage. Data from different sources, ranging for example from DNA and amino acid sequences to morphology and spatial distributions, are analyzed and a hypothesis of evolution is produced. This hypothesis is known as a cladogram if constructed under cladistic methods. It shows how the species are related to each other and what traits define groups. A cladogram is a very informative source of information and is not the end of a long process: it is the starting point for all kinds of questions ranging from population genetics to comparative biology.

Revealing the evolutionary pattern of taxa has considerable implications. Arguments about the importance of classifications based on history are well known for

most systematists (taxonomists, cladists and biogeographers), but in practice and for the majority of biologists, application of phylogenies prove to be more convincing. For example, knowing that humans share a close ancestor with rodents, we use mice as a model in clinical research to find cures for lethal diseases such as cancer and HIV, without risking the health of any person (McCune *et al.*, 1990). Before sending any human into space we first sent monkeys to study the effects of space travel on them that could affect humans. Albert, a rhesus monkey rode over 63 km in a V2 rocket in 1948 and died of suffocation during the flight (Simmonds, 1977). These examples and many others illustrate the importance of knowing where each species belongs in the tree of life. Reconstructing the history of life not only improves the way we understand evolution, it also provides a logical basis to help define species in taxa where this task is not easily done.

Known as flower chafers or fruit chafers, the cetonines are a subfamily of scarab beetles (Coleoptera: Scarabaeidae: Cetoniinae) widely distributed around the world. According to Krikken (1984) there are 3500 species distributed in 11 tribes. Some studies (Browne and Scholtz, 1995; Lawrence and Newton, 1995) have shown the monophyly of the Cetoniinae, but there is a not well supported phylogenetic hypothesis for the subfamily.

Six tribes are present in the Americas: Cetoniini, Cremastocheilini, Goliathini, Gymnetini, Trichiini, and Valgini. The New World Goliathini were reviewed at the taxonomical level by Morón and Ratcliffe (1989) as were the Valgini by Jameson and Swoboda (2005). The Gymnetini has been studied by Ratcliffe at the generic and species level the previous three decades (Ratcliffe, 1978; Morón and Ratcliffe, 1984; Deloya and

Ratcliffe, 1988; Ratcliffe and Deloya, 1992; Ratcliffe *et al.* 2001; Ratcliffe, 2004, 2005). The Cremastocheilini are not very well known and there is not a solid body of literature for this area. Warner (1985) described a *Cremastocheilus* and since then nothing else has been published. The Trichiini of North and Central America were reviewed by Howden (1968) but there is nothing comparable for the species of South America. The Cetoniini (Table 1) were treated by Hardy in 1988 and 2001. He provided a complete nomenclatural history of all the species in the American continents and proposed many synonyms at the genus and species level. As presented, all members of the American species (Table 2) of Cetoniini are included in the subtribe Euphoriina within four genera: *Stephanucha*, *Chlorixanthe*, *Euphoria* and *Euphoriopsis*. Schoch (1894) used Euphoriae to include all the American species of Cetoniini, but it was Schenkling (1921) who began using the subtribal name Euphoriina. In the Schenkling view of the Cetoniini, this tribe is composed of four subtribes: Cetoniina, Glyciphanina, Elaphinina and Euphoriina, with each restricted to a particular biogeographic region. Six genera were listed by Schenkling in the Euphoriina as follows: *Anatropis* Casey, *Chlorixanthe* Bates, *Euphoria* Burm., *Euphoriaspis* Casey, *Euphoriopsis* Casey and, *Stephanucha* Burm. No characters supporting this classification were presented.

From 1921 until the mid 1980s, no changes in the classification of the Cetoniini occurred until Krikken presented his work in 1984 integrating the entire diversity of Cetoniinae. He abandoned the use of the term Euphoriina, arguing that *"Schenkling recognized various subtribes and sections based on insufficient characters or purely on distribution."* Only two subtribes were proposed *"somewhat reluctantly,"* the Cetoniina and Leucocelina, each with a set of defining characters. He placed all American species

of Cetoniini in the Cetoniina, the latter a group distributed worldwide. As far as infra-subtribal classification, Krikken did not review it and listed the same genera Schenkling did. Twenty-three years later, Krikken (1984) represents the only work presenting a classification system based on characters integrating the entire diversity of the Cetoniinae.

The reaction to the system of Krikken (1984) was slow. In 1998 Krajcik republished a three volume update of the Coleopterorum Catalogous of Schenkling (1921) dealing with the Cetoniinae and titled "Cetoniinae of the World". The term Euphoriina appeared again in this work but Krajcik, maybe influenced by Krikken's work, showed doubt about its validity, via a question mark. The list of genera presented was the same as Schenkling and Krikken. The same year, Alan Hardy (1998) published the first of two works dealing with the American species of Cetoniini. The group was treated *sensu* Schenkling (1921), and Krikken's concepts were ignored. Hardy proposed several changes at the generic level as follows: *Anatropis* was synonymized with *Stephanucha* and *Euphoriaspis* (Casey), *Euphorhipis* (Casey), *Haplophoria* (Casey), *Isorhipina* (Casey) and *Rhipiphorina* (Casey) were synonymized with *Euphoria.* A key for the recognized genera (*Euphoriopsis*, *Stephanucha*, *Euphoria* and *Chlorixanthe*) was provided and comments on their validity were made: "*The standing of Euphoriopsis would seem to need further revision;*" "*Chlorixanthe … is approached in nearly every "unique" structure by some Euphoria*", and "*Stephanucha … merits generic standing*".

The second part of Hardy's work was published in 2001. In this paper, he dealt with the taxonomically complex genus *Euphoria*. Only 44 of 128 species and subspecies were recognized and these were placed in seven species groups. Unfortunately the

species groups were not explicitly defined and three species (entities) were considered *incertae sedis*.

In spite of the vast amount of work Hardy did compiling information about the group, the product did not solve all the existing confusion. No arguments supporting the new changes were provided and no phylogenetic method was used to support his new classification in light of evolution. During 1998, Sakai and Nagai published a book titled "The Cetoniine beetles of the World." It is an illustrated guide that again adds confusion to the classification of the group. The system that Krikken proposed in 1984 for the Cetoniini was implemented here, ignoring the Euphoriina of Schenkling. Surprisingly for this kind of work it provided an original list of genera for the American continents and resurrects *Anatropis*.

Lastly, in 2003 Matt Paulsen presented a talk at the Entomological Society of America meeting in Cincinnati, Ohio. He analyzed the American genera of Cetoniini and added in Cetoniini from other parts of the world using DNA sequence (28S) data. As presented by Paulsen, Euphoriina is a natural group. Additionally, just *Euphoria* and *Chlorixanthe* were considered valid genera.

Using representative taxa of all American genera, I performed a cladistic analysis of morphological characters. Taxa of Cetoniini from around the world were included to test the hypothesis of monophyly. Representatives from each one of Hardy's species groups of *Euphoria* were incorporated to improve the understanding we have of the evolution of the genus and a new classification for the subtribes of Cetoniini is proposed as result of the analysis.

MATERIALS AND METHODS

Examined Taxa

A total of 72 taxa were analyzed (Table 3) including representatives of all the recognized American genera as follows: 44 *Euphoria*; 1 *Stephanucha*; 1 *Euphoriopsis*; and 2 *Chlorixanthe*. Six Old World Cetoniini and 18 additional species representing different tribes of Cetoniinae where used as outgroups. Representatives of each *Euphoria* species group defined by Casey (1915) and Hardy (1998) were included to test their validity. For species with a high level of polymorphism, more than one specimen was included. Since there is no previous phylogeny for the Cetoniinae but there is some evidence suggesting its monophyly (Browne and Scholtz, 1998) the outgroup selection followed two main criteria. First a wide selection of taxa including most of the tribes of Cetoniinae were included to provide a base for future studies and to serve as a preliminary test of the monophyly of the tribes. Second, taxa from Cetoniini outside the American species were integrated to address the question regarding the monophyly of Euphoriina. (See Appendix 1).

Most specimens were borrowed from the following collections and individuals in the USA and Mexico: University of Nebraska State Museum (Brett Ratcliffe, Federico Ocampo); Essig Museum of Entomology, Berkeley, California (Cheryl Barr); University of Michigan, UMMZ Insect Division (Mark O'Brien); Instituto de Ecología, Xalapa, Mexico (Miguel Angel Moron); Texas A&M University Insect Collection (Ed Riley); Paul Skelley (Florida State Collection of Arthropods); Keith Philips (Western Kentucky University); and my personal collection.

Character selection

Material was analyzed using a Leica MZ-16 at the Laboratory of Systematics and Evolution in Western Kentucky University and in the Laboratory of Systematics at Purdue University. Specimens for dissection were soaked in boiling water for one hour and then for 48 hours in lactic acid. Mouthparts, wings, and genitalia were dissected and organized on glass slides for comparative analysis. Fifty-eight morphological characters were coded, including 14 from the pronotum, seven from the head, 13 from the mouthparts, seven from the elytra, one from the wings, six from the abdomen, eight from the legs and two from the male genitalia. Twenty multistate characters were included. For two species, *E. schotti* and, *E. westermanni*2 not enough material was available to allow for dissections. Only characters from males were coded. The data matrix is shown in Table 2. Missing characters were treated as "?" and characters absent were treated as "-". Terminology for the micro-sculpture was based on Harris (1979).

1. Pronotal sides: (0) medially not expanded; (1) medially expanded
2. Pronotal sides: (0) divergent or convergent in the last third; (1) parallel in the last third
3. Pronotal setosity: (0) glabrous; (1) sparsely setose; (2) densely setose
4. Pronotal derm: (0) Non velutinous or cretaceous; (1) velutinous or cretaceous
5. Pronotal punctuation: (0) absent; (1) sparsely punctuated; (2) densely punctuated
6. Pronotal rugae: (0) absent; (1) present
7. Pronotal basomedial lobe: (0) absent; (1) present, not covering the scutellum; (2) present, covering the scutellum

8. Pronotal horn or protuberance: (0) absent; (1) present
9. Pronotal base: (0) clearly arched above scutellum; (1) Not clearly arched, either straight or rounded.
10. Pronotal base: (0) sinuate; (1) non-sinuate
11. Anterior border of pronotum with central protuberance: (0) absent; (1) present
12. Lateral margin of pronotum: (0) completely emarginate; (1) emarginate in basal half only
13. Lateral suture of pronotum: (0) uniformly impressed; (1) weakly impressed in anterior half; (2) absent
14. Prosternum in lateral view with a greatly reduced anterior half: (0) absent; (1) present
15. Apex of the clypeus: (0) strongly projected upward; (1) slightly projected upward; (2) not projected upward
16. Apex of the clypeus (0) entire; (1) bilobed; (2) sinuate; (3) dentate; (4) with projection
17. Shape of the clypeus: (0) subtrapezoidal; (1) subquadrate
18. Frontoclypeal suture: (0) not evident; (1) evident
19. Lateral border of clypeus: (0) not defining internal zone; (1) projected upward delimiting an internal zone
20. Clypeal sculpture: (0) punctuate; (1) punctuate-strigated; (2) imbricate; (3) punctuate-imbricate
21. Frons with midline impressed: (0) absent; (1) present
22. Number of maxillary teeth in galea: (0) none; (1) one; (2) two; (3) four

23. Maxillary teeth in lacinia: (0) absent; (1) present
24. Second and third maxillar palpi segment more or less equal in size: (0) absent; (1) present
25. Lacinia clearly longer than wider: (0) absent; (1) present
26. Superior part of the big mandibular lobe: (0) approximately straight; (1) rounded
27. Mandibular lobes of almost the same height: (0) absent; (1) present
28. Molar area in mandibles: (0) smooth; (1) serrate, bumped, (not smooth)
29. Separation between mentum and submentum: (0) lacking deeply notched sides; (1) sides deeply notched
30. Prementum: (0) wider than mentum; (1) almost same size than mentum; (2) mentum wider than prementum
31. Labium base: (0) concave; (1) convex; (2) straight
32. Setae in the epipharynx: (0) in a complex array; (1) in a simple array. The majority of then long and projected forward
33. Epipharynx: (0) middle area glabrous; (1) middle area setose
34. Setae in anterior border of epipharynx: (0) normal; (1) thickened
35. Posthumeral emargination of the elytra: (0) present; (1) absent; (2) slightly pronounced
36. Elytra surface: (0) glabrous; (1) setose
37. Elytra articulation with thorax : (0) in a single lobe process; (1) in a glove-shape process
38. Elytron lines: (0) absent; (1) two or more; (2) one

39. Anterior border of the elytra in lateral view: (0) parallel to the body; (1) projected frontally
40. Elytral shape in lateral view: (0) clearly reduced after the humeral zone; (1) constant is shape after the humeral zone
41. Short transversal vein arms on wings: (0) juts left arm; (1) symmetrical right and left arms; (2) without arms; (3) just right arm; (4) bifurcated arms, left arm much longer
42. Lateral border of abdominal sternites: (0) rounded; (1) emarginate
43. Penultimate abdominal sternites strongly constricted at the spiracular level: (0) absent; (1) present
44. Pygidium: (0) anterior half setose, posterior half bare; (1) setae evenly distributed or completely glabrous
45. Pygidium rugosities: (0) concentric rugae; (1) punctulated; (2) non-concentric rugae
46. Pygidium: (0) non-velutinous or cretaceous; (1) with at least some cretaceous or velutinous patches
47. Metafemur carina: (0) absent; (1) present; (2) poorly defined
48. Metatibia expanded apically: (0) absent; (1) present
49. Hind tibia spurs: (0) symmetrical; (1) asymmetrical
50. Mesometasternal spine: (0) transversal line deeply impressed; (1) transversal line faint

51. Mesometasternal spine: (0) without margin or row of setae ; (1) with mesosternal apical margin extending upward; (2) with row of setae or punctures extending into the spine
52. Mesometasternal spine extending beyond the coxae level: (0) absent; (1) present
53. Mesometasternal spine compression: (0) absent; (1) laterally compressed; (2) basally compressed
54. Mesofemur inferior carina: (0) absent; (1) present; (2) not well defined
55. Parameres fusion: (0) separated; (1) fused dorsally more than 1/3 of the paramere length; (2) fused dorsally less than 1/3 of the paramere length; (3) ventrally fused
56. Parameres shape: (0) rectangular; (1) pointed apically; (2) slightly expanded apically; (3) greatly expanded apically

Cladistic analysis

The data matrix was constructed in WinClada (Nixon, 1999) and the analysis was performed under the parsimony criterion. The characters were coded as unordered and the matrix was analyzed under two schemes: equal weights (no weights) and implied weights. The non-weighted search was implemented in NONA (Goloboff, 1998) directly from WinClada and used the following parameters: hold 10000, hold/50, Mult*1000 (random addition sequence, 1000 replicates, TBR branch swapping). This was done five times on two occasions to make certain all the shortest tress were discovered.
Implied weights were implemented in PIWE (Goloboff, 1998) to evaluate the effects of weighting. The following parameters were implemented: hold 10000, hold/1000, amb-, Mult*200. Searches were implemented with concavity values from 1 to 6. The matrix construction, tree comparison and character mapping was implemented in WinClada. One

hundred replications were used to calculate the Bootstrap and Jacknife values in Winclada.

RESULTS AND DISCUSSION

The heuristic search of the equal weights data set produced 4012 equally parsimonious trees of 407 steps (CI=0.20, RI=0.61). The strict consensus trees, with and without character branch support respectively, are shown in figures 1 and 2.

Implied weights search assigns weights to the characters based on the amount of homoplasy that each character contributes to the tree. The lower the value of concavity, characters with high homoplasy have increasingly less influence on creation of the tree topology.

The number of trees and their fit values for each concavity calculated in PIWE value were as follow: K=1: 172 trees, Fit: 179.3; K=2: 13 trees, Fit 228.7; K=3: 1 tree, Fit: 264.1; K=4, 11 trees, Fit: 290.5; K=5, 13 trees, Fit 312.1; and K=6: 1 tree, Fit: 331.0. Because the high values of concavity downweight homoplasy less strongly those resulting trees are more similar to those found with non weighted searches. The consensus trees obtained from the implied weights search differ depending on the concavity value that is chosen. K=3 is the default value and the single tree discovered is shown in figure 3.

Euphoriina (Schoch, 1894) = Cetoniini (Leach 1815) NEW SYNONYMY

The subtribe Euphoriina was not supported in any of the weighting schemes used, even at the most drastic (i.e., lowest) values of concavity.

Oxythirea funesta, the only Leucocelina (*sensu* Krikken) included in the analysis, appeared inside Clade B, a major clade including other Cetoniina. This constitutes no reason to reject Krikken's classification of the Cetoniini subtribes, as it is probable that

Oxythirea is truly part of the Cetoniina and, because just one exemplar taxa for Leucocelina was used, the results are not conclusive in this regard.

The more inclusive Cetoniini (Clade C in Figures 3 and 4) appears supported by two homoplastic characters; the elytra-thorax articulation in a glove-like shape (Figure 1) and the mesosternal process basally compressed and apically expanded in shape. The position of *Tetraodhorrina* inside the Cetoniini clade only in the implied weights tree (K=3) is not considered a strong falsifier for this hypotheses but an artifact from the analysis. In all the other trees, *Tetraodhorrina* appears in the outgroup. This is a similar case to that found by Giribet *et al.* (2001) for the position of *Drosophila* in Arthropoda where characters highly homoplastic in the matrix result in an aberrant topology.

Two major clades were observed, represented in the tree as clade A and B (Figs. 2, 3, 5). Although these clades appeared in both the weighted and the unweighted trees they are not identical in composition. Members of clade A could be distinguished by the lateral border of the clypeus elevated and defining an internal zone and pronotum with rugae. Members of clade B have a simple lateral border of clypeus and do not present a pronotum with rugae. Another character that is very useful to distinguish between these two, but that it is more variable, is the midline in the frons that is present in most of the members of clade A and absent in most of the members of clade B.

In conclusion, the American genera of Cetoniini constitute a completely artificial group. This clade appears to be formed by just two monophyletic genera, *Chlorixanthe* and *Euphoria*.

***Chlorixanthe* Bates**

Of the currently recognized genera, *Chlorixanthe* is the only one that appears to be monophyletic. Nevertheless, the position of this genus in the Cetoniini is not absolutely clear. In the weighted trees (K=1,2,3,6), this genus (with two species) appears in clade A as sister to *Tretraodorhina* . and these as sister to *Euphoria geminata*. All four species share a nearly complete fusion of the parameres in the male genitalia. This character is only present in *E. hirtipes* as well. In the majority-rule tree *Chlorixanthe* is located as the sister group of Cetoniini and, in the strict consensus tree it is one clade of a basal pentotomy. *Chlorixanthe* exhibits two unique characters: the anterior border of the epipharynx is formed by strong setae and the elytra is lacking costae.

***Stephanucha* Burm., 1842 = *Euphoria* Burm., 1842 NEW SYNONYMY**

Anatropis Casey, 1915

Stephanucha thoracica falls out apically within a clade composed only of species of *Euphoria*. The species appears closely related to *Euphoria hirtipes* in both the weighted and unweighted analyses sharing the homologous character of the presence of an epipharynx with a simple array of seta.

***Euphoriopsis* Burm., 1842 = *Euphoria* Burm., 1842 NEW SYNONYMY**

Euphoriopsis hera appears closely related to *Euphoria precaria* in the weighted trees, and one homoplastic character supports this group: the relative same height of the mandibular lobes. The sexes in these two species are also dimorphic; a character that was presumed unique for *Euphoriopsis hera* and *Euphoria leseuri* by Hardy (1988) and that at the current knowledge is exclusive and only shared among these three species. In the unweighted trees, *Euphoriopsis hera* appears related to *Euphoria arizonica* and

Euphoria avita, a clade that is not very well supported. Even though it is not clear precisely where this taxon fits within the Cetoniini, it is very evident that it most likely does not constitute a valid genus.

***Euphoria* Burm. 1842**

Euphoria as currently defined constitutes a polyphyletic genus. Hardy's species groups for *Euphoria* were based on overall similarity and it was expected that the monophyly of this genus would not be well supported. Additionally, none of the seven species groups proposed were supported in any of the analyses performed. Similarly none of the *Euphoria* subgenera proposed by Casey (1915) were monophyletic. Of all the discovered clades, just one was supported by an uncontroverted homology when K=3 in the weighted trees. The *Euphoria* species *kerni*+ *texana*+ *subtomentosa*+ *basalis* share a non-smooth molar surface in the mandibles.

The position of *E. schotti* and *E. westermanni2* varies greatly in the trees. This fluctuation is attributed to the amount of missing data for these taxa as just one specimen of each of these species was available and dissections were not permitted. But it does appear that *E. schotti* may be a basal lineage while *E. westermanni* is more derived within *Euphoria*.

Euphoria holochrolis Fall, 1905 and *E. limbalis* Fall, 1905 were treated by Hardy (2001) as subspecies of *E. fulgida* (Fab., 1775). According to the tree obtained by the equal weights search, *E. holochrolis* constitutes a valid species and is the sister group of *"fulgida" (E. fulgida1 + E. fulgida2) + limbalis*. Two main characters separate *holochrolis* from *"fulgida"+limbalis*: the base of the labium is concave and the abdomen

is emarginated in "*fulgida*"+*limbalis* and, in *holochrolis* the base of the labium is concave and the abdominal sternites are rounded laterally.

The clade (*holochrolis*(*limbalis*(*limbalis2*+*fulgida*))) is defined by the combination of three characters: body dorsally glabrous, the pronotum densely punctuated and with rugae and, prementum wider than mentum. *Euphoria limbalis2* a species collected in Monticello, Florida by G. Fairchild in 1935 constitutes a new species that I'm currently describing.

Old World Affinities

Lacordaire (1856) suggested that *Euphoria*, *Erirhipis* (synonymized with *Euphoria* by Gemminger and Harold, 1869) and *Stephanucha* should be merged with some Old-World genera in the genus *Euryomia*. Lacordaire's ideas were not completely wrong. The present results seem to support Lacordaire's ideas. The only reason to keep *Euphoria* is the lack of a better classification but these changes are necessary for clarification. It is possible that the genus might be better split into two or more genera but for now this is not proposed.

CONCLUSIONS

The current arrangement of the Cetoniini in the American continents is chaotic and similar in this respect to the chaos existing in *Phyllophaga*, for example (Skelley, 2003). Many of the species (Clade B) share closer relationships with species in other continents than with species in the Americas. A planetary scale revision looks like the only way to solve this problem.

It is hard to determine if the obtained results are caused by limited number of taxa or limited number of phylogenetically informative characters. I tend to think that morphological characters in Cetoniinae, even being very hard to find and define are a good tool to define relationships. Adding more taxa and characters from different sources (DNA, larvae) looks like the logical way to proceed. Except for *Chlorixanthe*, all American genera as defined are paraphyletic or polyphyletic; it does not make any sense to organize the American species into groups when it is clear that the differences with the Old World genera are not well understood. It is very likely that many species will be moved to other genera and a completely new classification will be available for the Cetoniini, based on all World taxa and not limited to a particular geographical region.

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APPENDIX

Leach, 1815	Schenkling, 1921	Krikken, 1984	Hardy, 1988
Cetonida	Cetoniina, Glyciphanina, Elaphinina and Euphoriina	Cetoniina and Leucocelina	Euphorina + ??

Table 1. Classification of the Cetoniini.

* Because of Hardy's work just dealt with the American species is not clear what other groups despite Euphorina were included in the Cetoniini.

Schenkling, 1921	**Krikken, 1984**	**Hardy, 1988**	**Orozco, 2007 (this work)**
Anatropis	*Anatropis*	*Stephanucha*	*Chlorixanthe*
Chlorixanthe	*Chlorixanthe*	*Chlorixanthe*	*Euphoria*
Euphoria	*Euphoria*	*Euphoria*	
Euphoriaspis	*Euphoriaspis*	*Euphoriopsis*	
Euphoriopsis	*Euphoriopsis*		
Stephanucha	*Stephanucha*		

Table 2. Classification of the American species of Cetoniini.

Species		Tribe	Distribution
1. *Diplognatha sp.*	O	Diplognathini	Africa
2. *Porphyronota sp.*	O	Diplognathini	Africa
3. *Niphetophora sp*	O	Diplognathini	Africa
4. *Cotinis nitida*	O	Gymnetini	New World
5. *Gymnetis coturnix*	O	Gymnetini	New World
6. *Desicasta lobata*	O	Gymnetini	New World
7. *Euselates ornata*	O	Taenioderini	Oriental
8. *Clerota budda*	O	Taenioderini	Oriental
9. *Tetraodorhina sp.*	O	Stenotarsini	Madagascar
10. *Coptomia oliveri*	O	Stenotarsini	Madagascar
11. *Theodosia rodriguesi*	O	Phaedimini	Oriental
12. *Phaedimus meridionalis*	O	Phaedimini	Oriental
13. *Mycteristes rhinophyllus*	O	Phaedimini	Oriental
14. *Lomaptera bicolorata*	O	Schizorhinini	Oriental
15. *Poecilopharis schochi*	O	Schizorhinini	Australian, Oriental
16. *Lophorhina sp.*	O	Goliathini	Africa
17. *Mesorhina sp.*	O	Goliathini	Africa
18. *Cheirolasia burkei*	O	Goliathini	Africa
19. *Oxycetonia jucunda*	I	Cetoniini	Oriental
20. *Oxythyrea funesta*	I	Cetoniini	Europe
21. *Cetonia aurata*	I	Cetoniini	Europe
22. *Rhabdotis sabrina*	I	Cetoniini	Africa
23. *Protaetia fusca*	I	Cetoniini	Oriental, New World
24. *Elaphinis irrorata*	I	Cetoniini	Africa
25. *Euphoria avital*	I	Cetoniini	New World
26. *E. basalis1*	I	Cetoniini	New World
27. *E. basalis2*	I	Cetoniini	New World
28. *E. biguttata1*	I	Cetoniini	New World
29. *E .biguttata2*	I	Cetoniini	New World
30. *E. lineoligera1*	I	Cetoniini	New World
31. *E. linoligera2*	I	Cetoniini	New World
32. *E. canescens*	I	Cetoniini	New World
33. *E. subtomentosa1*	I	Cetoniini	New World
34. *E. subtomentosa2*	I	Cetoniini	New World
35. *E. scabiosa*	I	Cetoniini	New World
36. *E. histrionica*	I	Cetoniini	New World
37. *E. fascifera*	I	Cetoniini	New World
38. *E. pulchella1*	I	Cetoniini	New World
39. *E. pulchella2*	I	Cetoniini	New World
40. *E. pulchella3*	I	Cetoniini	New World
41. *E. candezei*	I	Cetoniini	New World
42. *E. fulgida1*	I	Cetoniini	New World
43. *E. fulgida2*	I	Cetoniini	New World
44. *E. fulgida3*	I	Cetoniini	New World
45. *E. limbalis1*	I	Cetoniini	New World

46. E. limablis2	I	Cetoniini	New World
47. E. dimidiata	I	Cetoniini	New World
48. E. lurida	I	Cetoniini	New World
49. E. schotti	I	Cetoniini	New World
50. E. kerni	I	Cetoniini	New World
51. E. texana	I	Cetoniini	New World
52. E. westermanni1	I	Cetoniini	New World
53. E. westermanni2	I	Cetoniini	New World
54. E. leseuri	I	Cetoniini	New World
55. E. herbacea	I	Cetoniini	New World
56. E. subguttata	I	Cetoniini	New World
57. E. steinheili	I	Cetoniini	New World
58. E. punicea	I	Cetoniini	New World
59. E. precaria	I	Cetoniini	New World
60. E. hirtipes	I	Cetoniini	New World
61. E. iridescens	I	Cetoniini	New World
62. E. arizonica	I	Cetoniini	New World
63. E. devulsa	I	Cetoniini	New World
64. E. geminata1	I	Cetoniini	New World
65. E. geminata2	I	Cetoniini	New World
66. E. nitens	I	Cetoniini	New World
67. E. sepulchralis	I	Cetoniini	New World
68. E. leucographa	I	Cetoniini	New World
69. Stephanucha thoracica	I	Cetoniini	New World
70. Euphoriopsis hera	I	Cetoniini	New World
71. Chlorixanthe flavoviridis	I	Cetoniini	New World
72. Chlorixanthe propingua	I	Cetoniini	New World

Table 3. Species included in the analysis. I: Ingroup, O: Outgroup

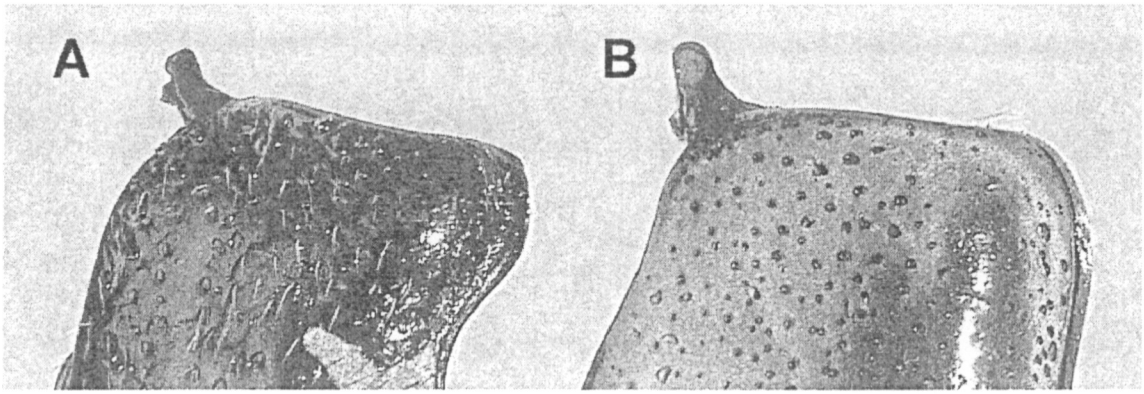

Figure 1. Thorax-elytron articulations. A: Cetoniini; B: Goliathini

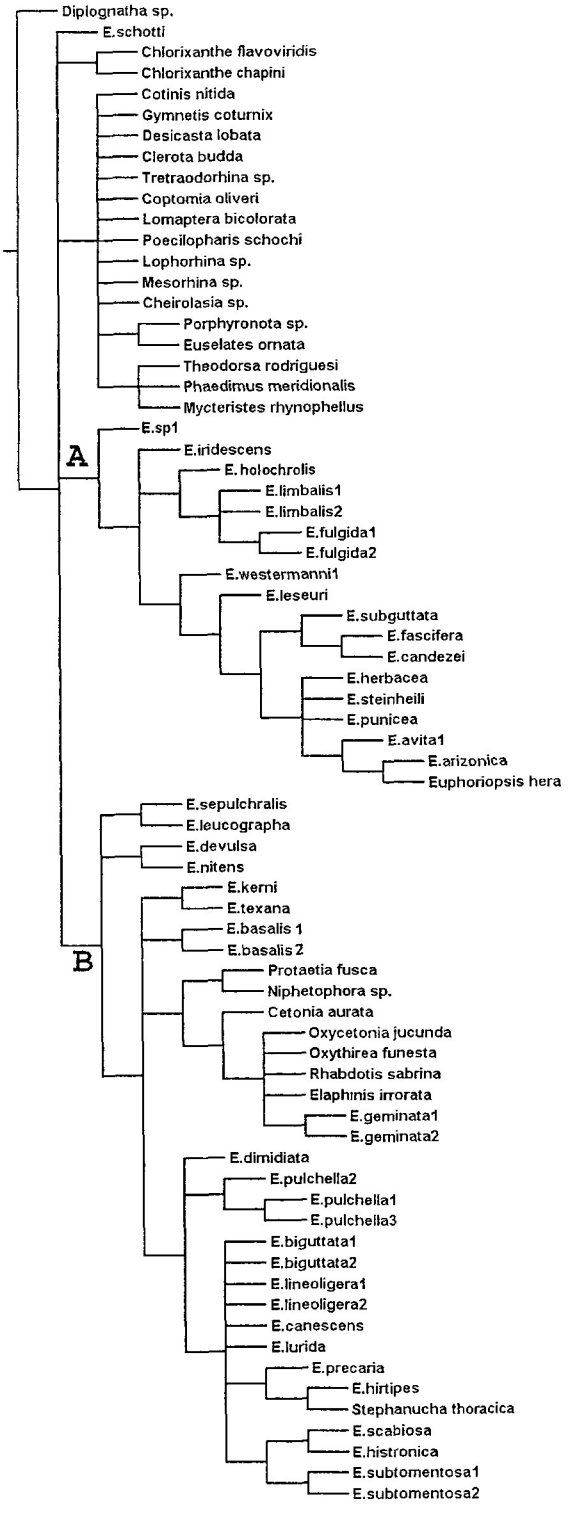

Figure 2. Strict consensus with equal weights tree

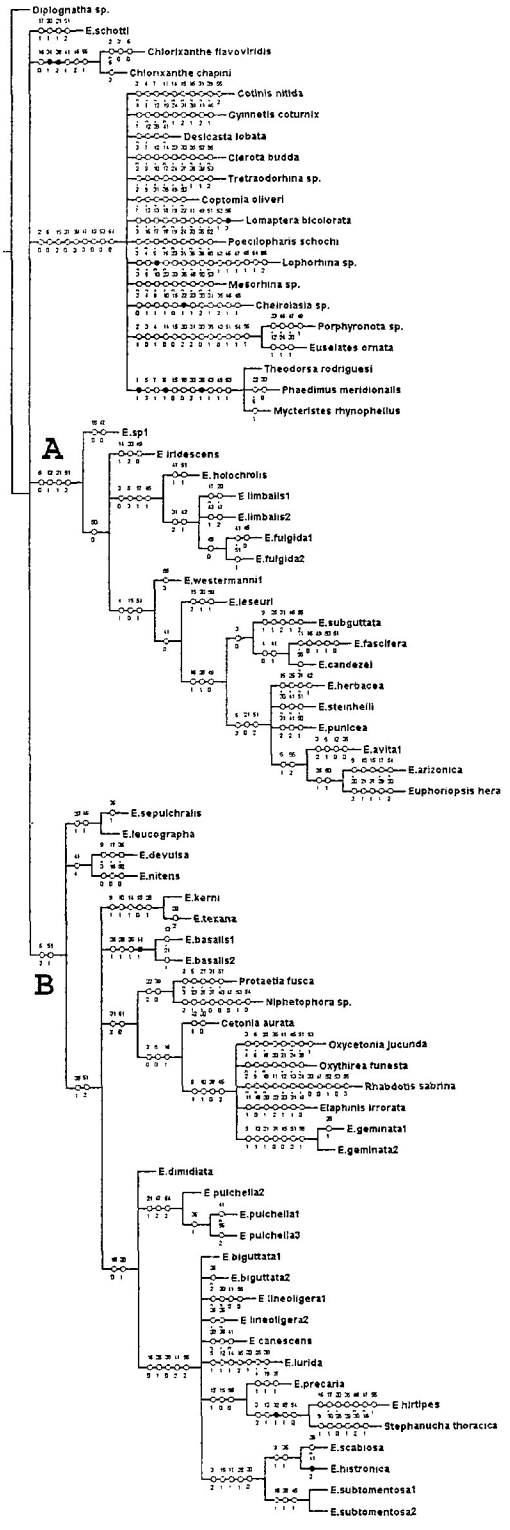

Figure 3. Strict consensus tree of the equal weights search with characters.

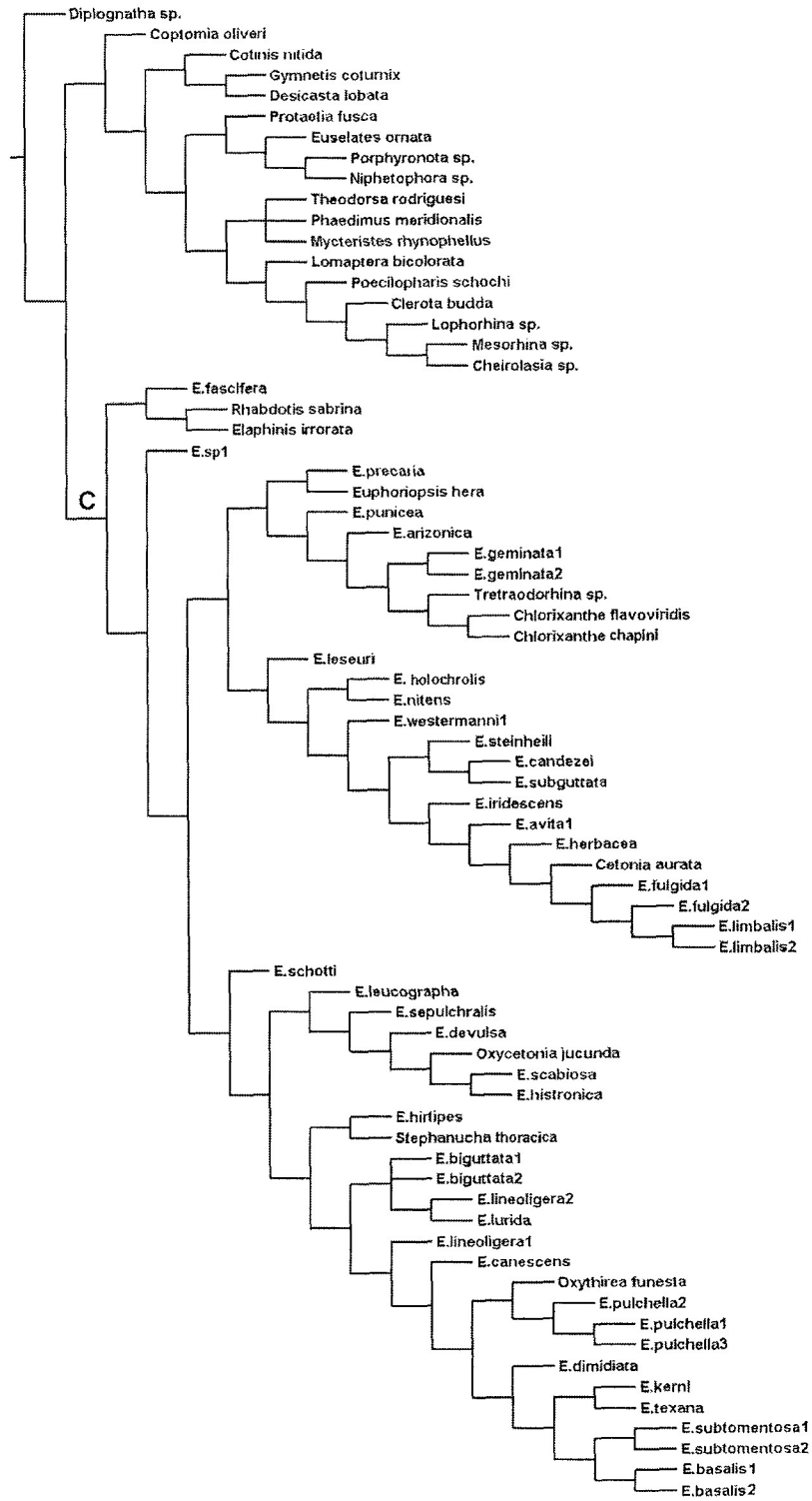

Figure 4. Implied Weights K=3 tree.

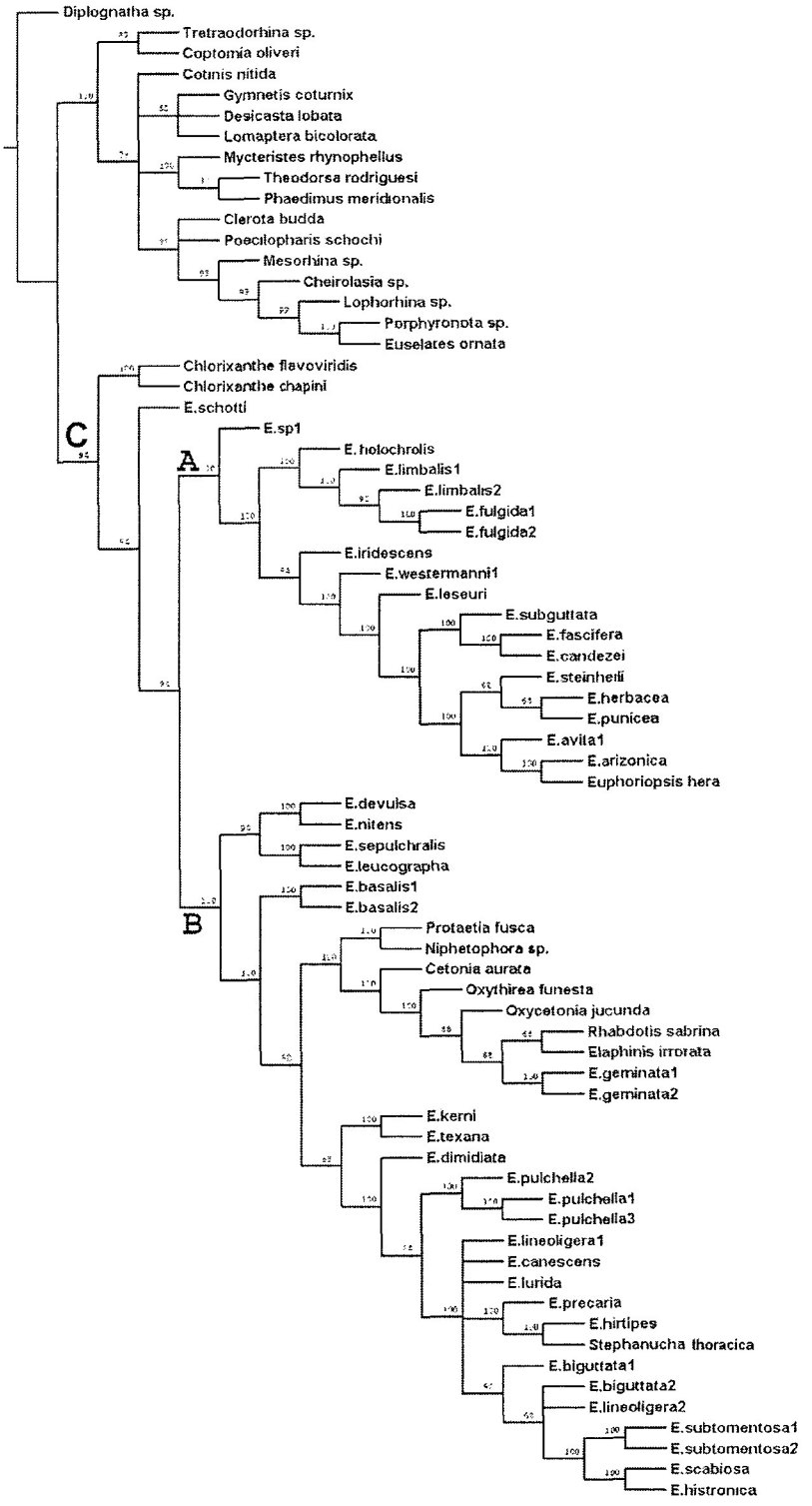

Figure 5. Majority rule tree

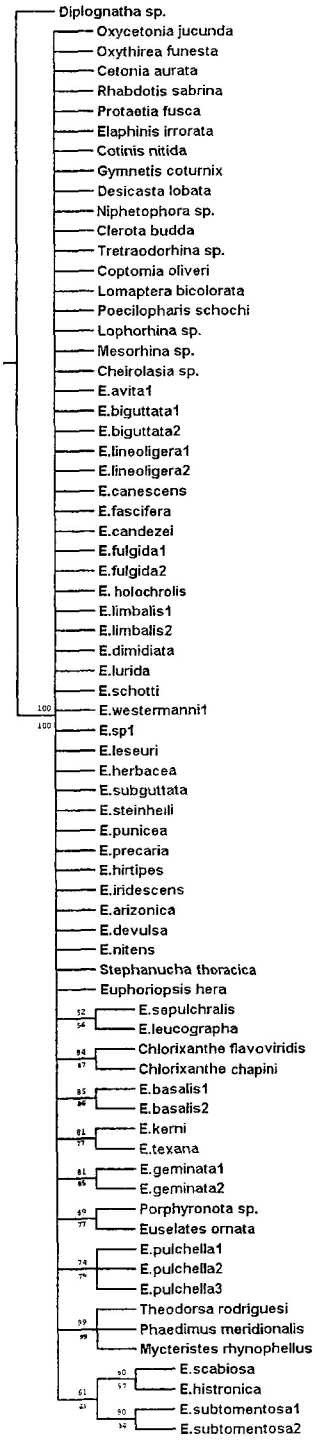

Figure 6. Bootstrap (top) and Jacknife (botton) values. Support values above 50% are shown.

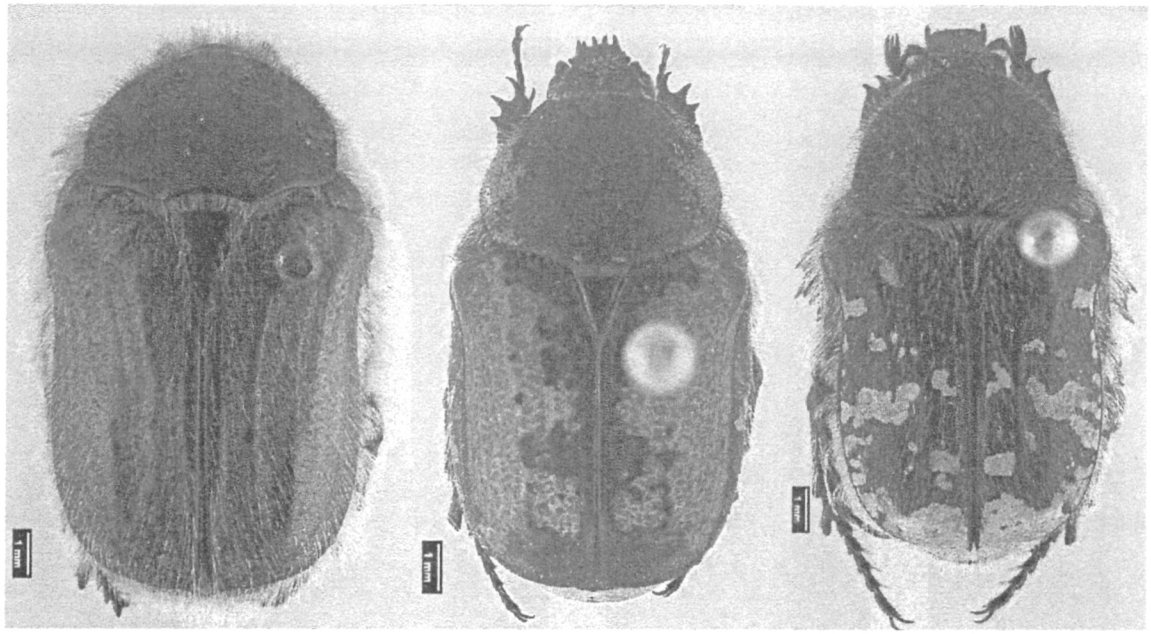

Figure 7. From left to right: *Euphoria hirtipes, E. thoracica, E. scabiosa*

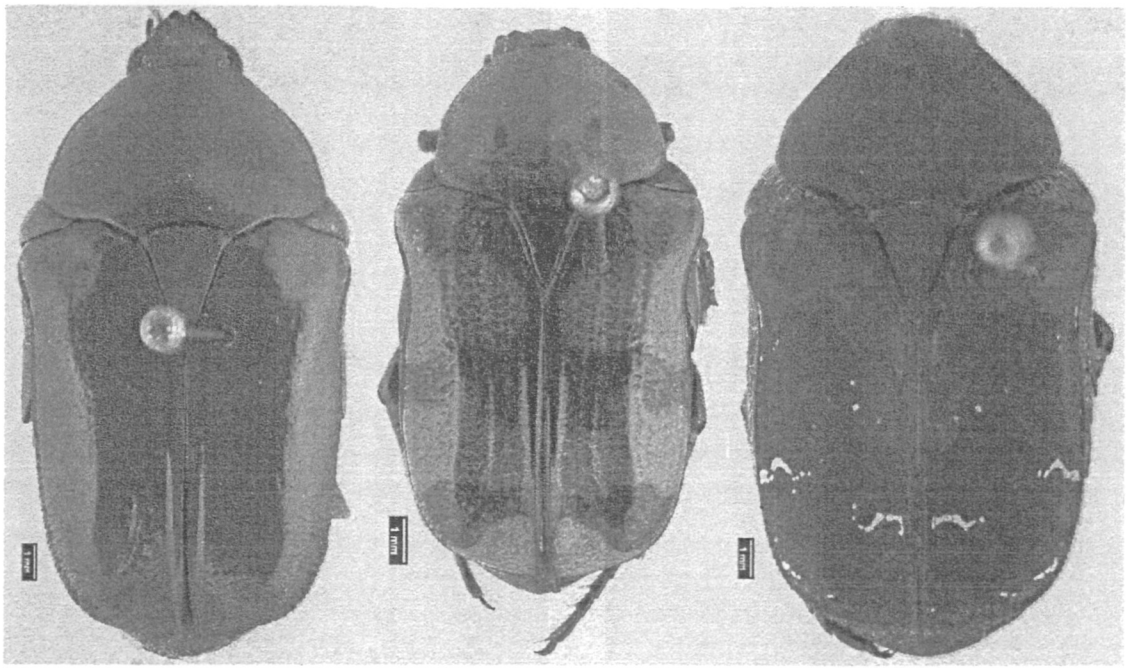

Figure 8. From left to right: *Euphoria candezei, E. fascifera, E. westermanni*

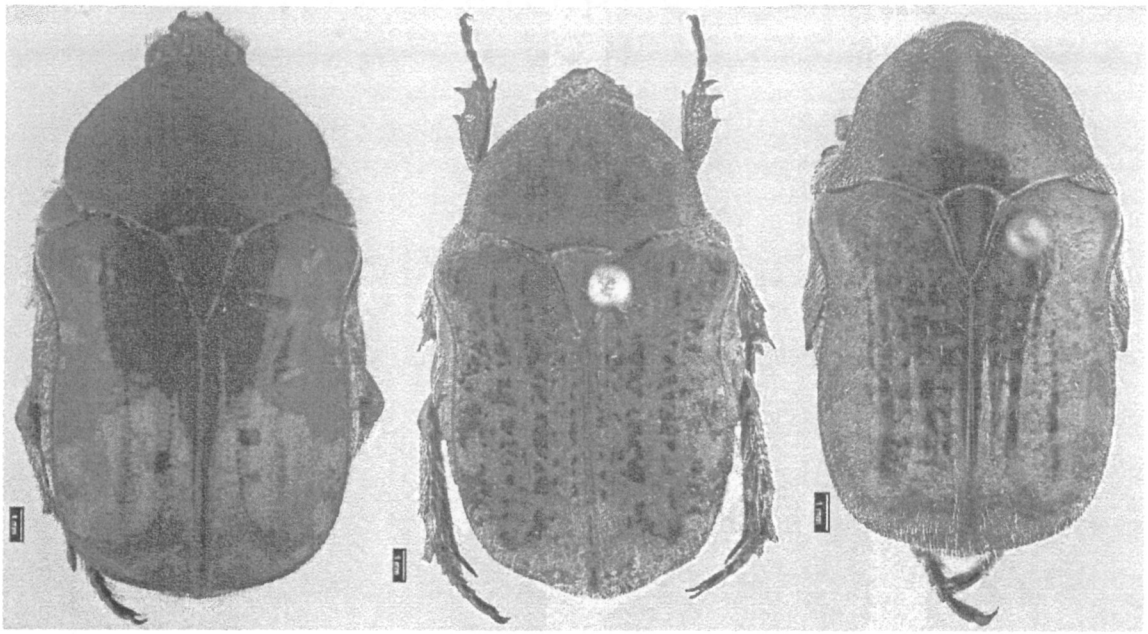

Figure 9. From left to right: *Euphoria hera, E. precaria, E. iridescens*

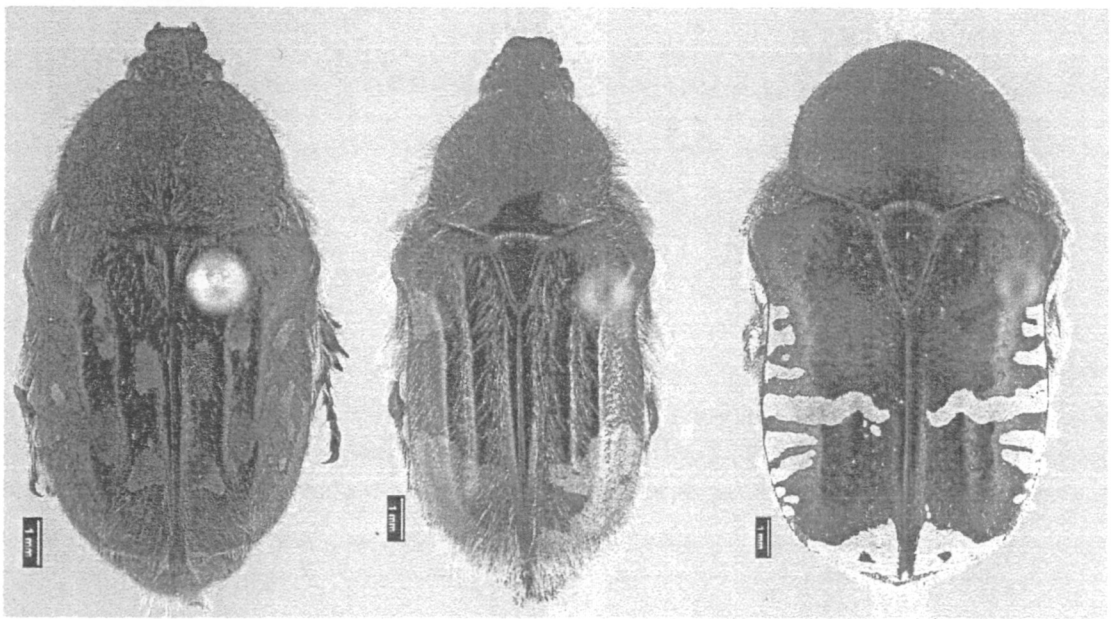

Figure 10. From left to right: *Euphoria basalis, E. subtomentosa, E. biguttata*

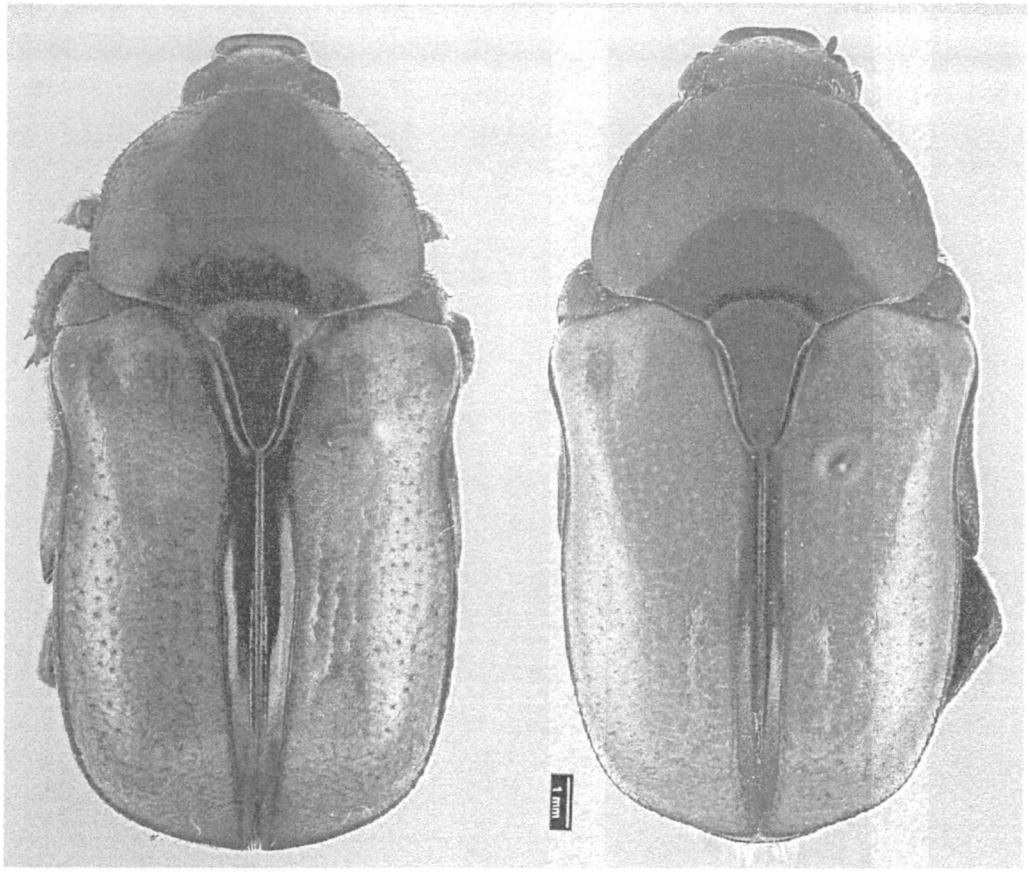

Figure 11. From left to right *Chlorixanthe propingua*, *Chlorixanthe falvoviridis*

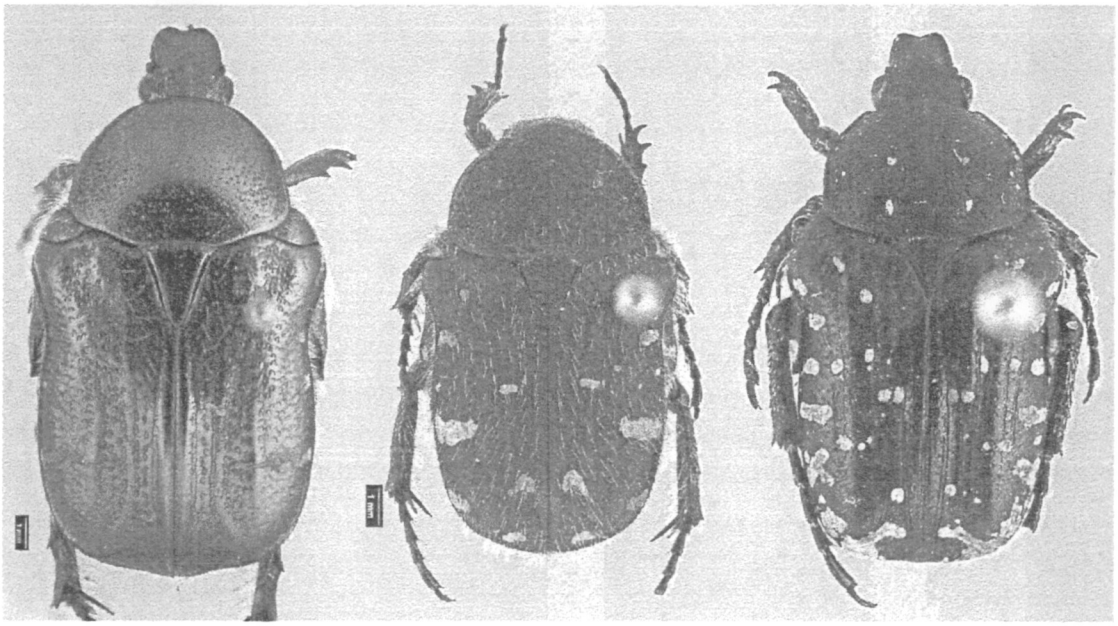

Figure 12. From left to right: *Cetonia aurata*, *Oxycetonia jucunda*, *Oxythyrea funesta*

CETONIINAE OF GHANA

Abstract

A field trip during summer 2006 to Ghana with the purpose of collecting cetoniines resulted in the capture of 19 species. These records are added to the existing available literature and illustrations for some of the collected species are provided. A new record for the first species of Cetoniinae living in bat guano in a cave is also given.

Introduction

Ghana is situated on the west coast of Africa. This country has a rich stock of biological diversity as it lies within the three main bio-geographical zones, namely: the south western portion within the Guineo-Congolian, the middle belt within the Guineo-Congolian/Sudanian transition, and the northern-tip of the country within the Sudanian zone.

Despite the lack of information on the full coverage of the biological resources of the country in such areas as marine and other aquatic ecosystems, the terrestrial records presently include about 2,974 indigenous plant species, 504 fishes, 728 birds, 225 mammals, 221 species of amphibians and reptiles. Three species of frogs, one lizard, and 23 species of butterflies have been reported to be endemic.

For insects other than butterflies there is not much information available. As part of the Ghana Insect Project lead by Keith Philips, an exploration of the fauna of Cetoniinae in the country was conducted.

Materials and Methods

Five localities were surveyed during this trip as follows:

Shai Hills: Lowland region with shrubs, grasslands and forest covering the hills. Many of the trees are the introduced neem tree from India. There are great differences between open areas of savannah and the areas of forest. Some caves are located in the area in the hills.

Atewa range: Moist semi-deciduous rain forest. This area is currently under high pressure of deforestation due to bauxite mining interests.

Bobiri: Lowland forest. Under high pressure of deforestation due to continued active logging. Also heavy untilization for forest products including bushmeat and palm wine.

Bomfobiri: Lowland savannah with shrubs. There is some limited galleries of forest along streams. Cape buffalo as well as other species are present.

Volta region: Heterogeneous region of mixed deciduous and semideciduous forest and cultivated areas. Some shrubs distributed in the hills. Small remnants of moist forest still exist such as that found in the valley below and east of Afadjato Mountain and Tagbo Falls.

The insects were collected with aerial traps baited with fruit . The traps consisted of 2 liter empty plastic soda containers baited with rotten banana, plantains, pineapple or a mix of fruit. In the case of fruit that was too fresh, beer or palm wine was added to speed up the fermentation process. In general, the traps were located as high as possible in natural borders of the habitat in the shade.

Results

A total of 19 species where collected distributed in seven tribes: Cetoniini, Gymnetini, Diplognathini, Cremastocheilini, Goliathini, Trichiini and Valgini. Cetoniini was the most diverse tribe, and *Pachnoda* the most common genus collected.

The greatest diversity was from Bomfobiri with six species. The only species of Cremastocheilini collected were located in a nest of termites in the lowlands of Shai Hills.

Stethodesma strachani was the only species of Gymnetini collected. Two species of *Charadrognatha* were collected always in traps positioned low in trees. The majority of the specimens were located in Van-Someren butterfly traps baited with banana and located at the soil level in the Bobiri area.

Pachnoda marginata (Figure 2) was observed to live in the caves of frugivorous bats. All stages of the beetle (larvae of all instars, pupae and adults) were collected in the guano. The adults seems to emerge and live the cave. No observations of the imago feeding on the guano were made. At the current knowledge this constitutes the first record of a Cetoniinae larvae feeding on bat guano. This data contributes to the knowledge on the evolution of the group and how different habitats had been colonized and utilized.

No specimens of *Goliathus* were collected but are mentioned by individuals working in Bobiri and Atwea range as present in the area. Helicopter beetles (as they are called in the zone) are greatly affected by deforestation since they need big trunks to complete their life cycle.

Trichines and valgines are not common in the traps. The few specimens of trichines collected were recovered from Flight Intercept Traps, and the valgines (the smallest beetles collected) were picked up while sitting on flowers.

The complete list of Cetoniinae known from Ghana is compiled from Joly (2001), records from a trip our colleague Allan Mudge (Oregon Department of Agriculture) made in Oct. 19 – Nov. 5, 2006 and our efforts in June-July, 2006 is presented in Table 1.

TABLE 1. Complete list of the Cetoniinae of Ghana.

Alleuscoma viridula
Argelina sp.
Atrichelaphinis deplanata
Caelorhina thoreyi
Campsiura congoensis
Charadronota acutangula
Charadronota quadrisignatha
Charadronota pectoralis
Charadronota soror
Chlorocala africana
Chlorocala nigricolis
Chlorocala similis
Chnodrorrhina abbreviata
Chordodera quinquelineata
Coenocylus calcaratus
Cyclophorellus cincticollis
Cymophorus sp.
Cyprolais pythia
Cyrtothyrea sp.1
Cyrtothyrea sp.2
Dicronorhina cavifrons
Diplognatha gagates
Diplognatha viridis
Diphrontis cruenta
Dymusia cyanea
Eriulis variolosa
Eudicella frontales
Gnathocera angustata
Gnathocera bilineata
Gnathocera flavovirens
Gnathocera hyacinthina
Gnathocera trivittata
Goliathus regius
Hadrodiplognatha herculeana
Leucocelis maraisi
Lophorrhina pentachordia
Lophorrhina quinquelineata
Marmylida hilaris
Marmylida marginella
Mecynorhina polyphemus
Megalleucosma allardi
Megalorhina harrisi
Niphobleta niveosparsia
Niphobleta squamipes
Oplostomus sp.
Pachnoda ardoini
Pachnoda concolor
Pachnoda cordata
Pachnoda marginata
Pachnoda orphanula
Pachnoda postica
Pachnoda rubrocincta
Pachnoda tridentata
Pedinorhina septa
Plaesiorrinella recurva
Plaesiorrinella watkinsiana
Polybaphes angustata
Polybaphes bella
Polybaphes sanguinolenta
Polybaphes scalaris
Polystalactita stellata
Psacadoptera arborescens
Psacadoptera bosqueti
Pseudoinca admixtus
Pseudoinca incoides
Pseudinca macgillavryi
Pseudoinca marmoratus
Rhabotis pontyi
Stephanorhina guttata
Stephanorhina simillima
Stethodesma strachani
Taurhina nireus
Tmesorrhina iris
Tmesorrhina tridens
Undetermined 1.
Undetermined 2.

FIGURES

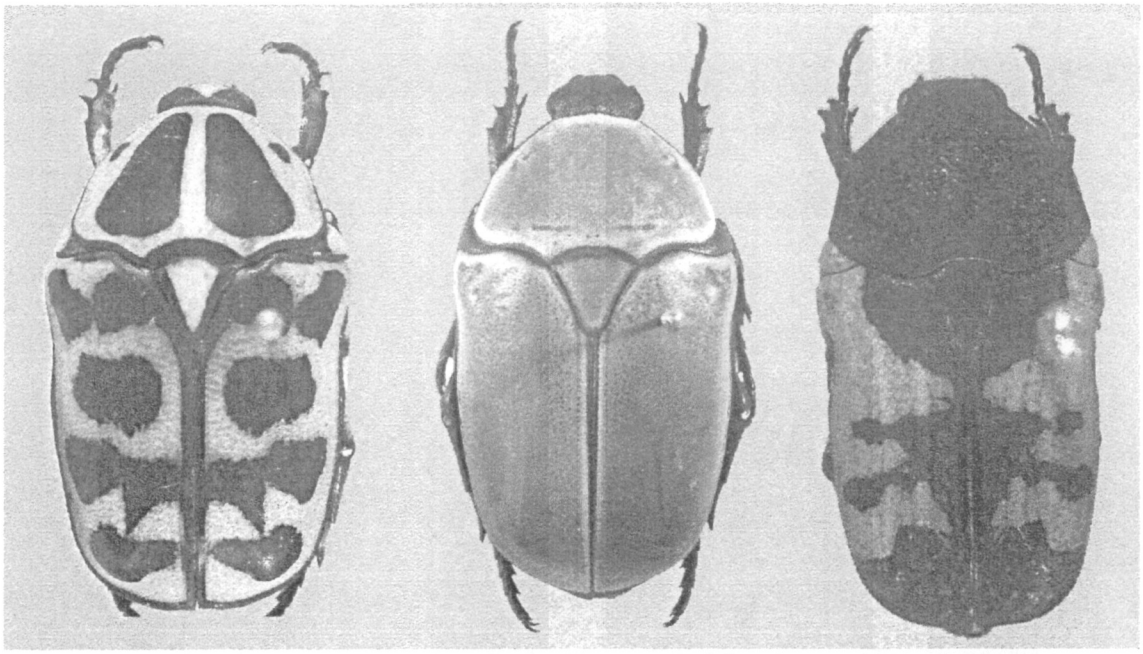

Figure 1. *Pachnoda cordata*, *Pachnoda marginata*, *Polybaphes sanguinolenta*

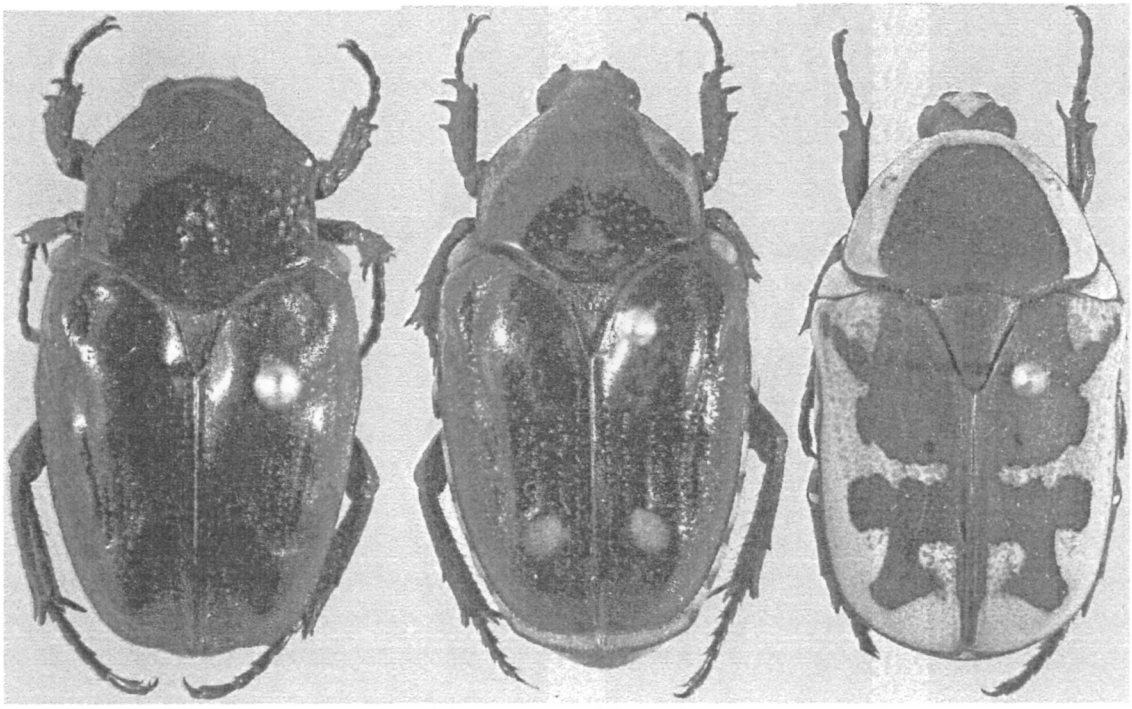

Figure 3. *Charadornota quadrisignata* dark form, *Charadornota quadrisignata* spotted form, *Pachnoda tridentata*

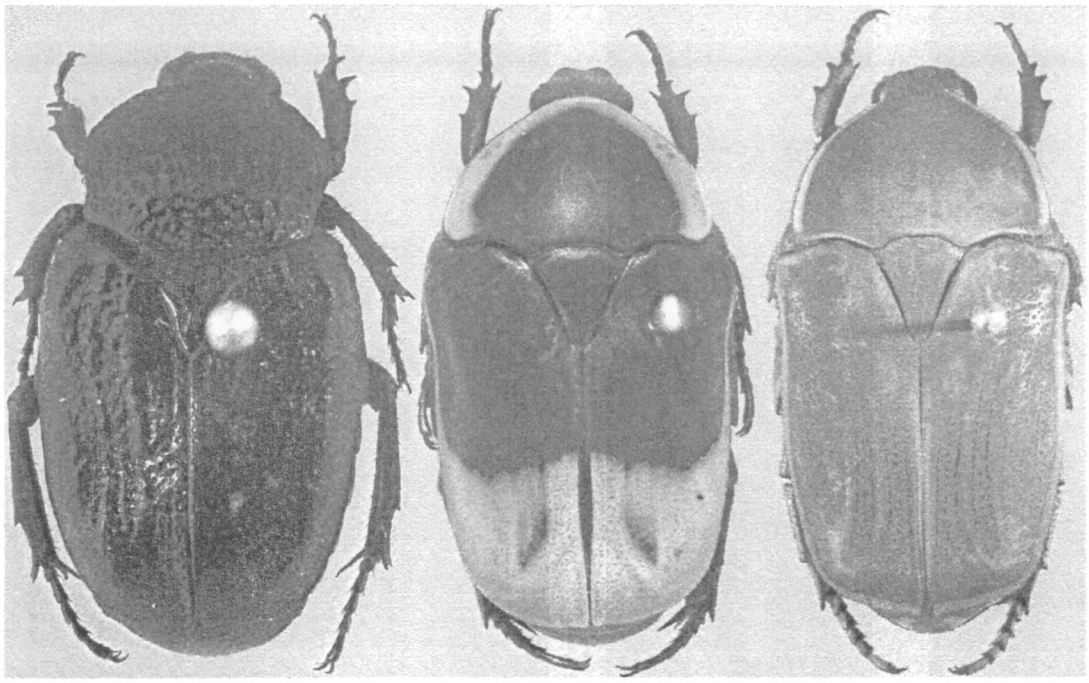

Figure 4. *Charadronota sopor, Pachnoda orfanula, Marmalyda marginella*

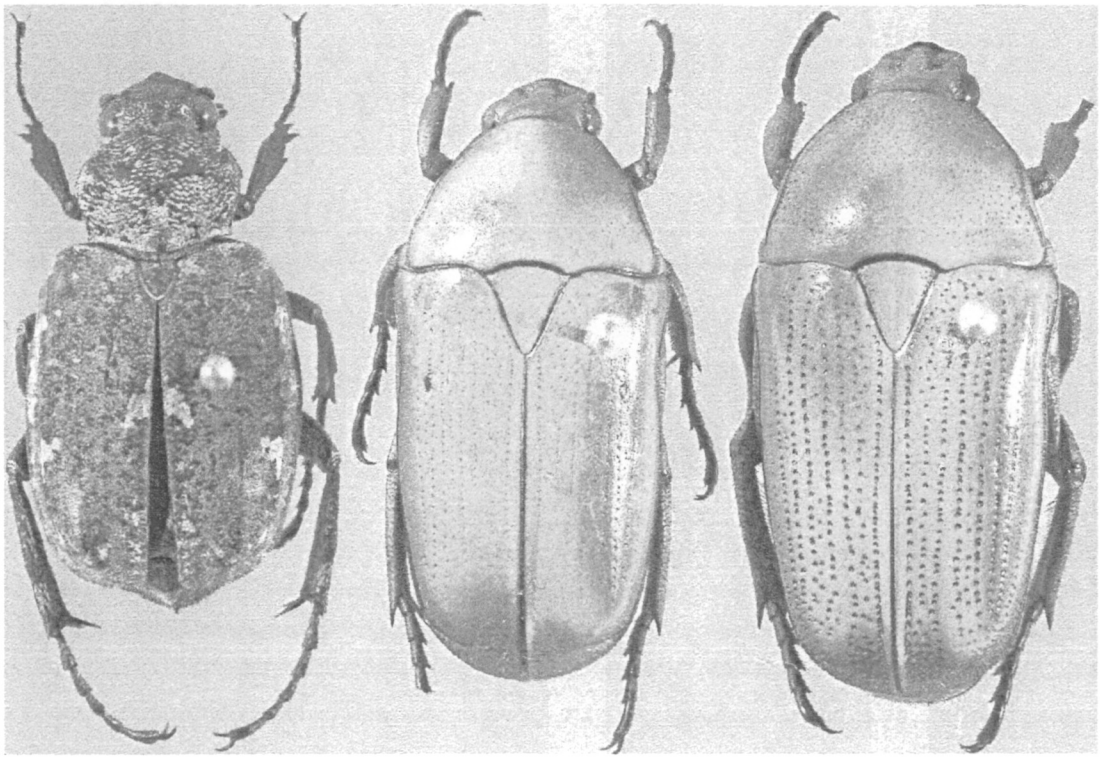

Figure 5. *Pseudoinca* sp. *Clorochala africana, Chlorocala similis.*